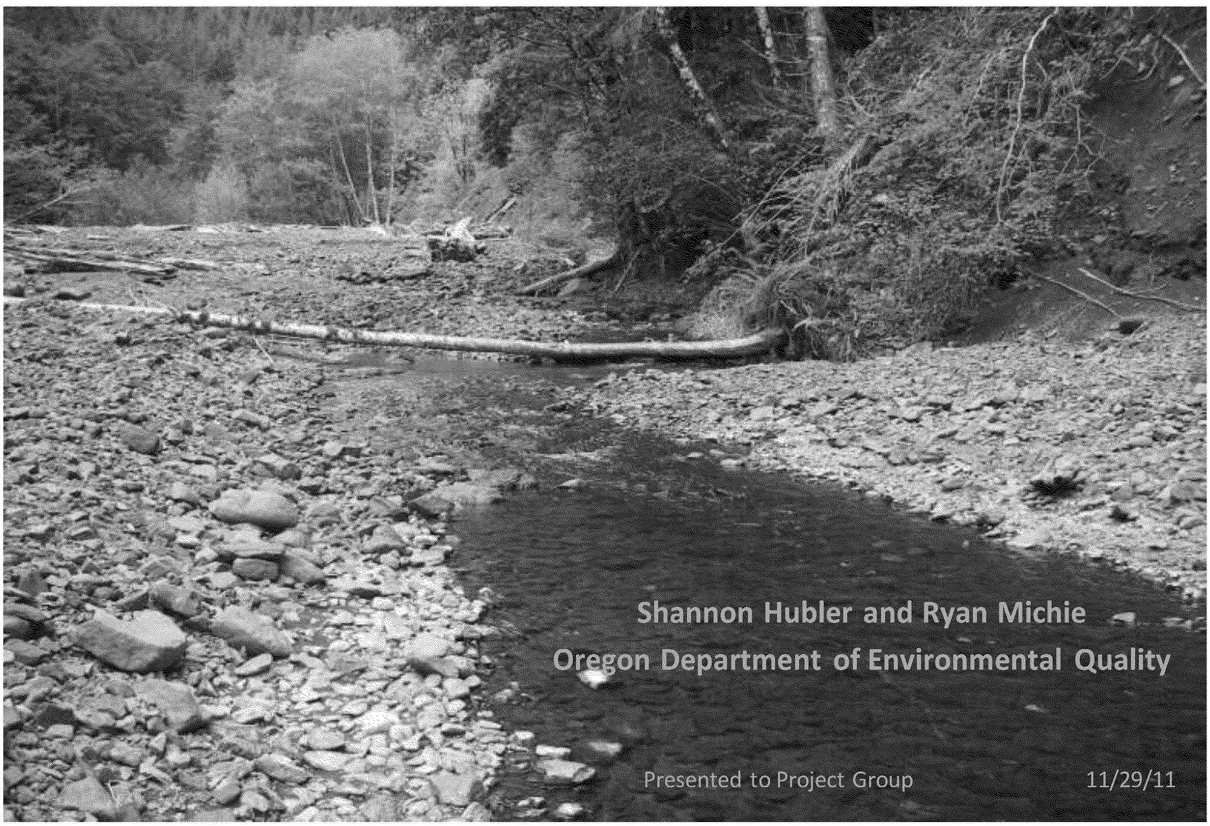
Use of a biological index to address sediment impairments in the Mid-Coast



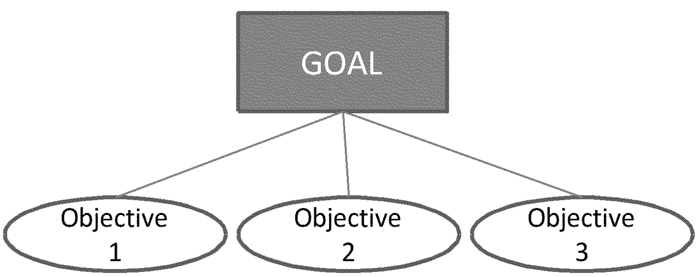
Shannon Hubler and Ryan Michie
Oregon Department of Environmental Quality

Presented to Project Group 11/29/11

State of Oregon Department of Environmental Quality

<u>Goal</u>:

Interpret the narrative sediment standards into a repeatable quantitative sediment target that can be used to assess waterbodies for the development of sediment TMDLs in the Mid-Coast.



What is Oregon's sediment standard?

"The formation of appreciable bottom or sludge deposits or the formation of any organic or inorganic deposits deleterious to fish or other aquatic life or injurious to public health, recreation, or industry may not be allowed"

OAR 340-041-0007 (12)

"Waters of the State shall be of sufficient quality to support aquatic species without detrimental changes in the resident biological communities"

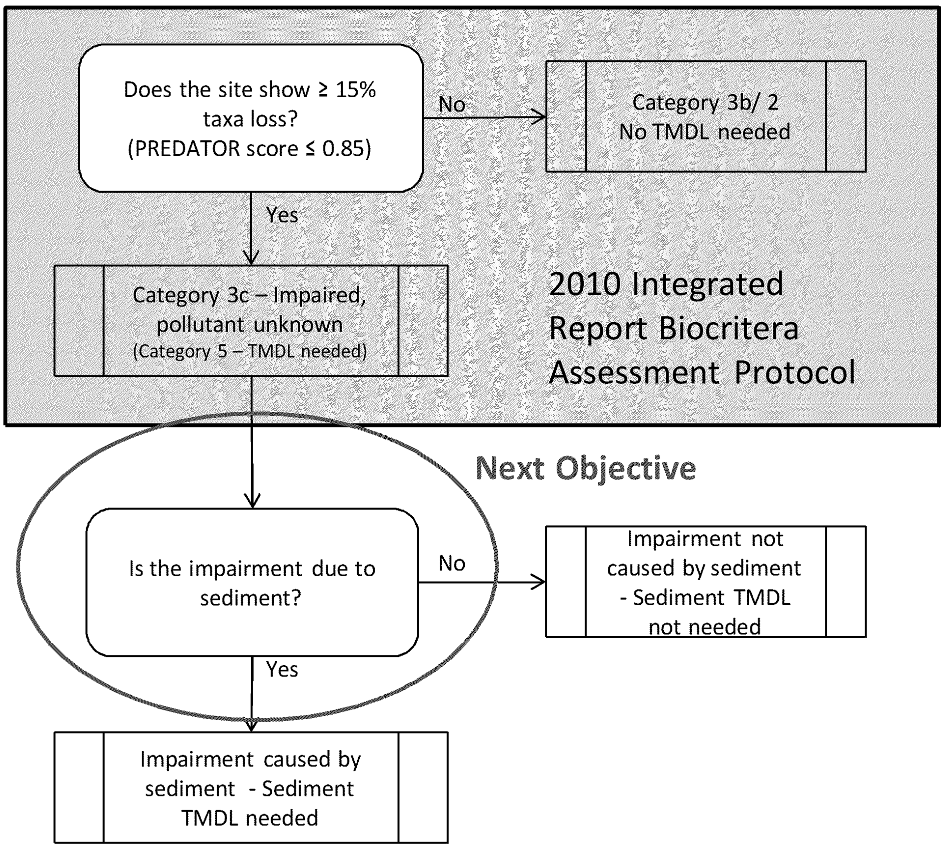
OAR 340-41-027

<u>Objective 1</u>:
Define what constitutes "*detrimental changes" or "deleterious*".

<u>Proposed method</u>:

Use 303(d) assessment methodology developed for the biocritera (aka PREDATOR model).

Biocriteria Assessment Protocol



<u>Objective 2</u>:

Define quantitatively the sediment target that demonstrates excessive sedimentation is a contributing factor to the biological impairment

Objective 2.1
Method to determine if sedimentation is the pollutant

Objective 2.2
Define the target benchmarks

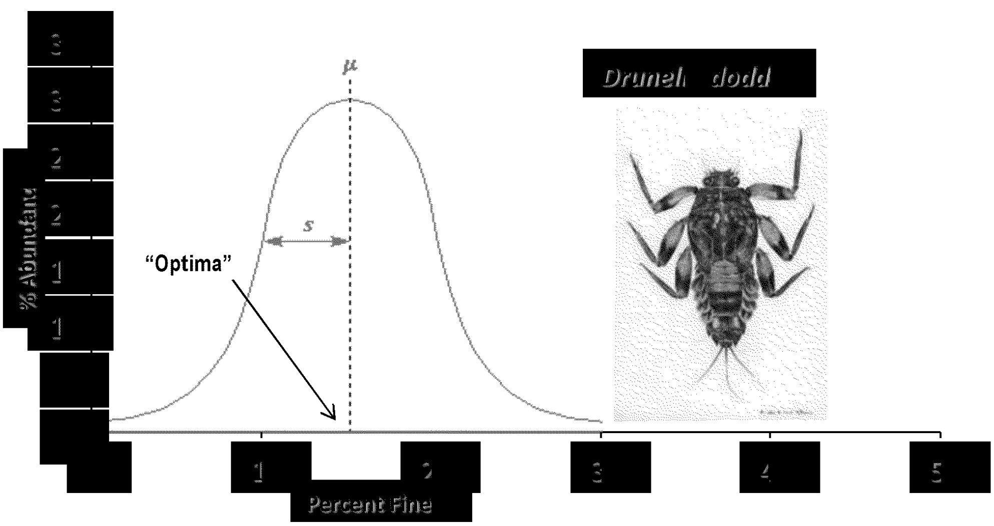
<u>Proposed method</u>:

Biologically inferred weighted average approach (Stressor ID model)

Two methods to set target benchmarks

Weighted average inferences (Stressor ID)

Macro invertebrates have an optimal biological preference for certain sediment conditions (optima).



Weighted Average Inferences

Observed taxa	Relative Abundance	WA opt	
Rhyacophila Betteni Gr.	0.23	13.7	3.2
Drunella doddsi	0.06	14	0.8
Simulium	0.15	16	2.4
Hesperoperla pacifica	0.11	16.4	1.8
Chironomini	0.32	16.8	5.4
Antocha	0.01	18.6	0.2
Zaitzevia	0.12	19.4	2.3
	1.0		**16.1**

Fine sediment score (FSS)

Setting Target Benchmarks

- Method 1: Classification
  - Benchmarks across groups
- Method 2: Modeling
  - Site specific benchmarks
  - Each site has unique expectations
- Distribution of reference scores
  - Percentiles, standard deviations
  - DEQ’s standard RCA approach = 75^{th} and 90^{th} percentiles
  - Balance TI and TII errors

Method 1: Erodibility

- Erodible and Resistant classification

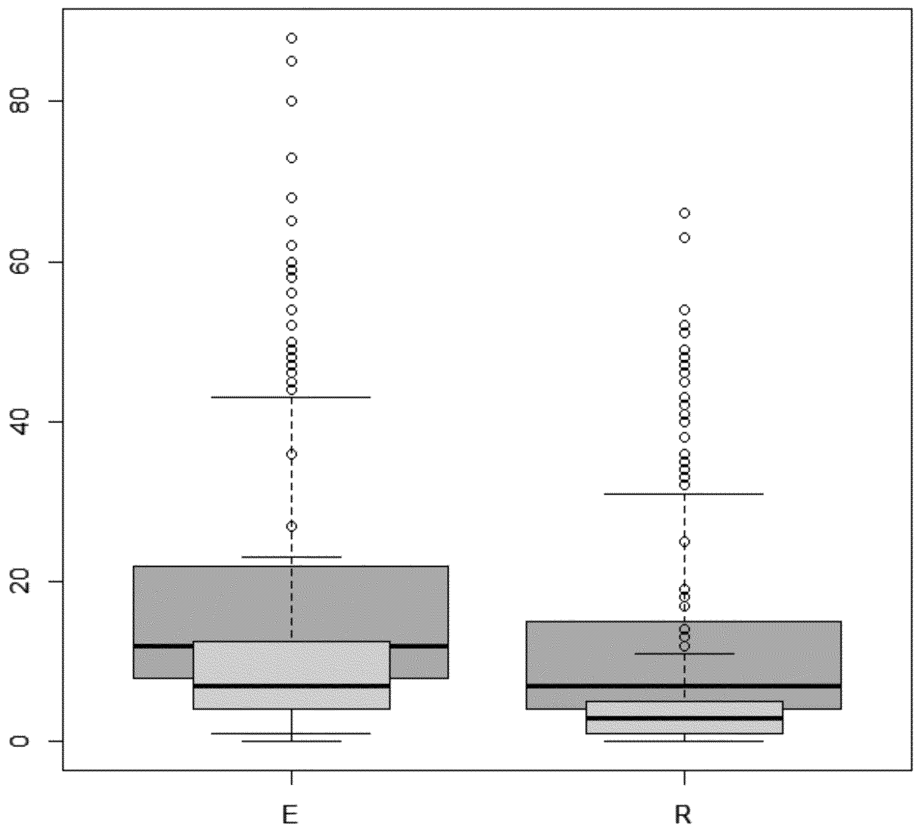
  % Erodible lithology in watershed
    - > 40% = Erodible (n = 66)
    - < 40% = Resistant (n = 223)

- FSS Benchmarks (reference percentiles)

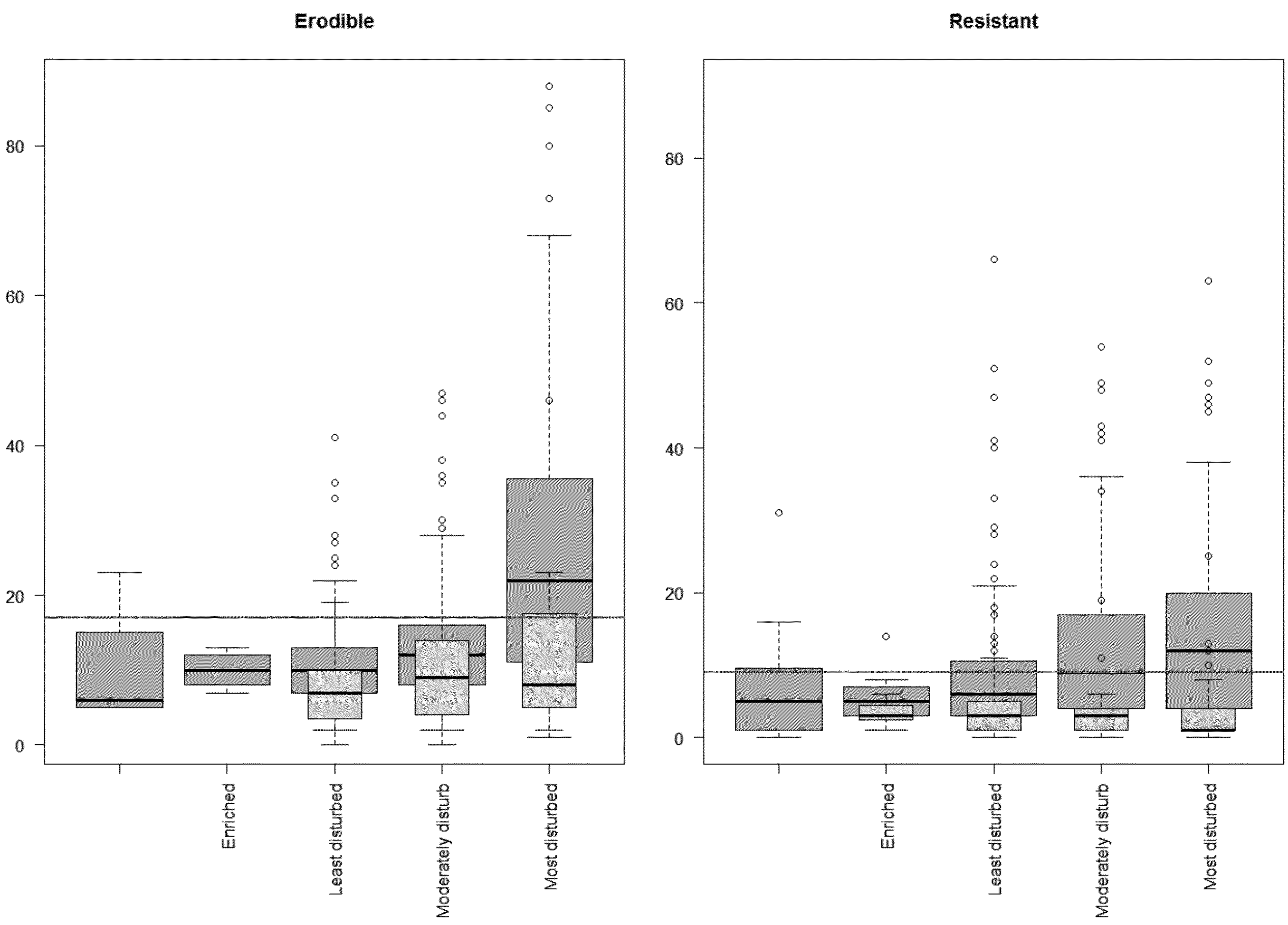
	Fine Sediment Score (FSS)		
Lithology	Good (<75^{th})	Fair	Poor (> 90^{th})
Erodible	0-11	12-17	> 17
Resistant	0-4	5-9	> 9

Erodibility : Reference and Test

Fine
Sediment
Score
(FSS)



Erodible (E): > 40% erodible lithology in watershed


Erodible
Resistant
0
20
40
60
80
Enriched
Least disturbed
Moderately disturb
Most disturbed

Method 1: Pros/Cons

Pros

- simple
- Some similarities to literature
  - Bryce et al. 2010: western mountainous streams
    - < 5% fines for full protection of sediment sensitive vertebrates
    - < 3% fines for macroinvertebrates
  - ODFW benchmarks for Coho ESU
    - < 10% = Good, > 30% = Poor
    - 2005 Monitoring Report

Cons

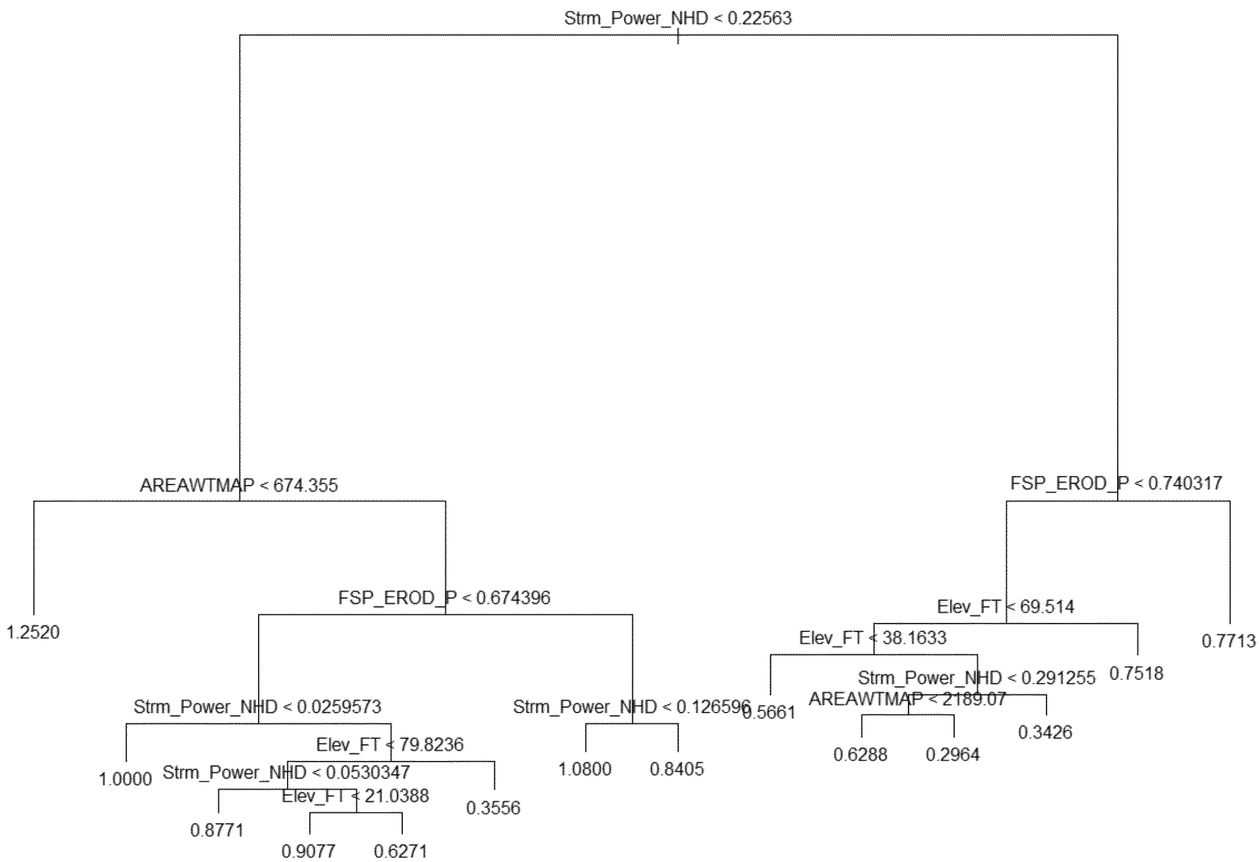
- assumes erodibility in the watershed is the only factor driving FSS
- exploratory analyses point to several other key variables with similar levels of influence on FSS
- Perception that one size fits all

Method 2: Modeling Site Specific FSS

- Reference sites only
- Adjust FSS for natural gradients (predictors)
  - latitude, longitude, elevation
  - Air temperature, Precipitation
  - Watershed area, Flow, Gradient, Stream Power
  - Lithology (% erodible)
  - Categorical:
    - Ecoregion 3, Eco4, Basins, Lithology groups, Lithology (site)
- A lot of work completed by Ryan to improve predictors

Random Forests Modeling

- Looked at other techniques, settled on RF
- Final Model
  - Continuous and categorical predictors
  - Can deal with missing predictors
  - Allegedly can’t be overfit
    - 500+ regression trees
  - r^2 values more accurate
  - Grey box?


Strm_Power_NHD < 0.22563
AREAWTMAP < 674.355
FSP_EROD_P < 0.740317
1.2520
FSP_EROD_P < 0.674396
Elev_FT < 69.514
Elev_FT < 38.1633
0.7713
0.7518
Strm_Power_NHD < 0.291255
Strm_Power_NHD < 0.0259573
Strm_Power_NHD < 0.126596
0.5661
AREAWTMAP < 2189.07
0.3426
Elev_FT < 79.8236
0.6288
0.2964
1.0000
Strm_Power_NHD < 0.0530347
1.0800
0.8405
Elev_FT < 21.0388
0.3556
0.8771
0.9077
0.6271

Modeling Results

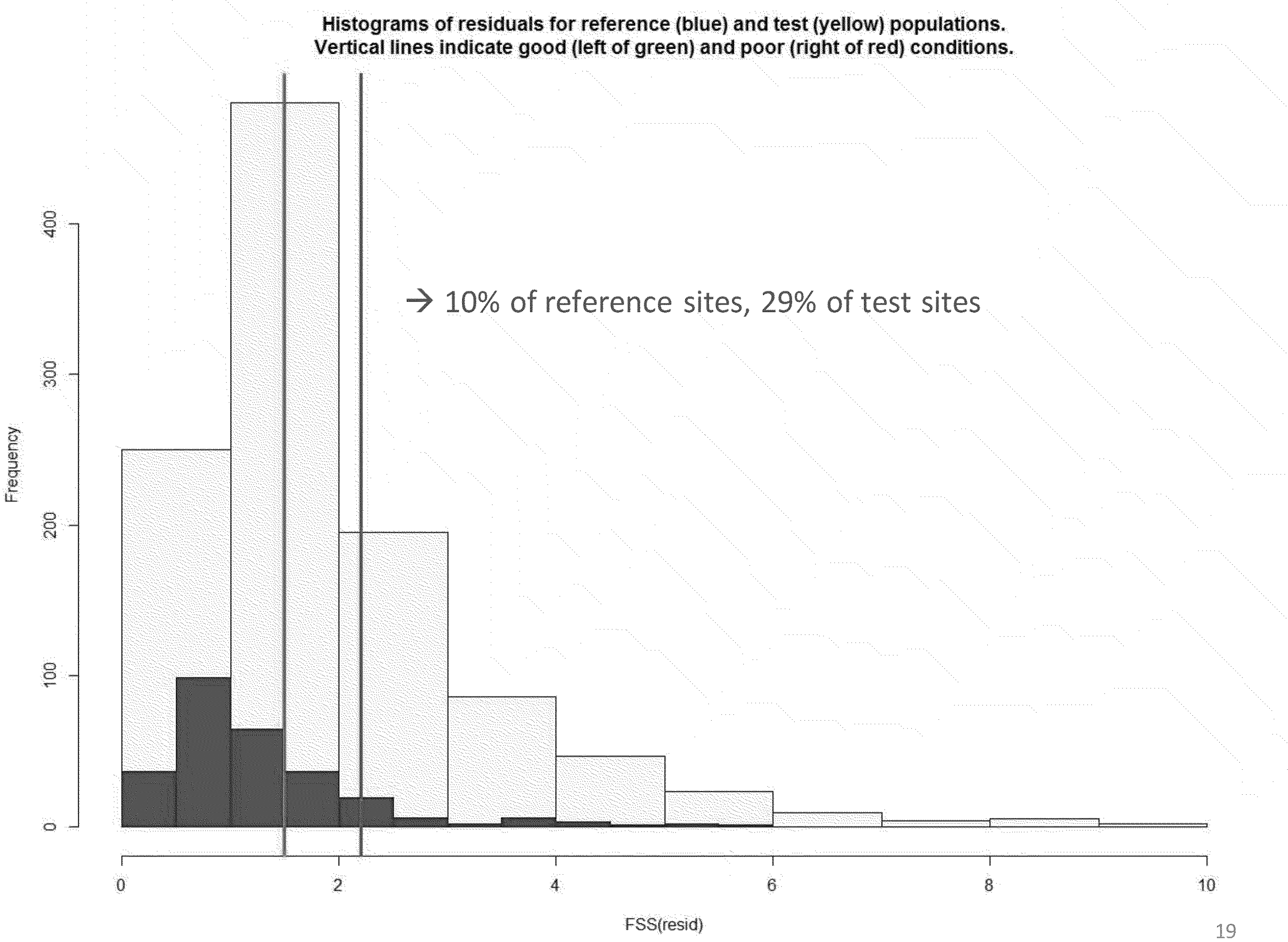
- 4 predictors of reference condition FSS
  - -Precipitation -Stream Power
  - -Elevation -% Erodible
- Site specific expectations for FSS
- Use percentiles as reference benchmarks
  - 75^{th} and 90^{th}
- How much greater is FSS_{obs} than FSS_{exp}?

  > 2.2x = Poor

  < 1.5x = Good

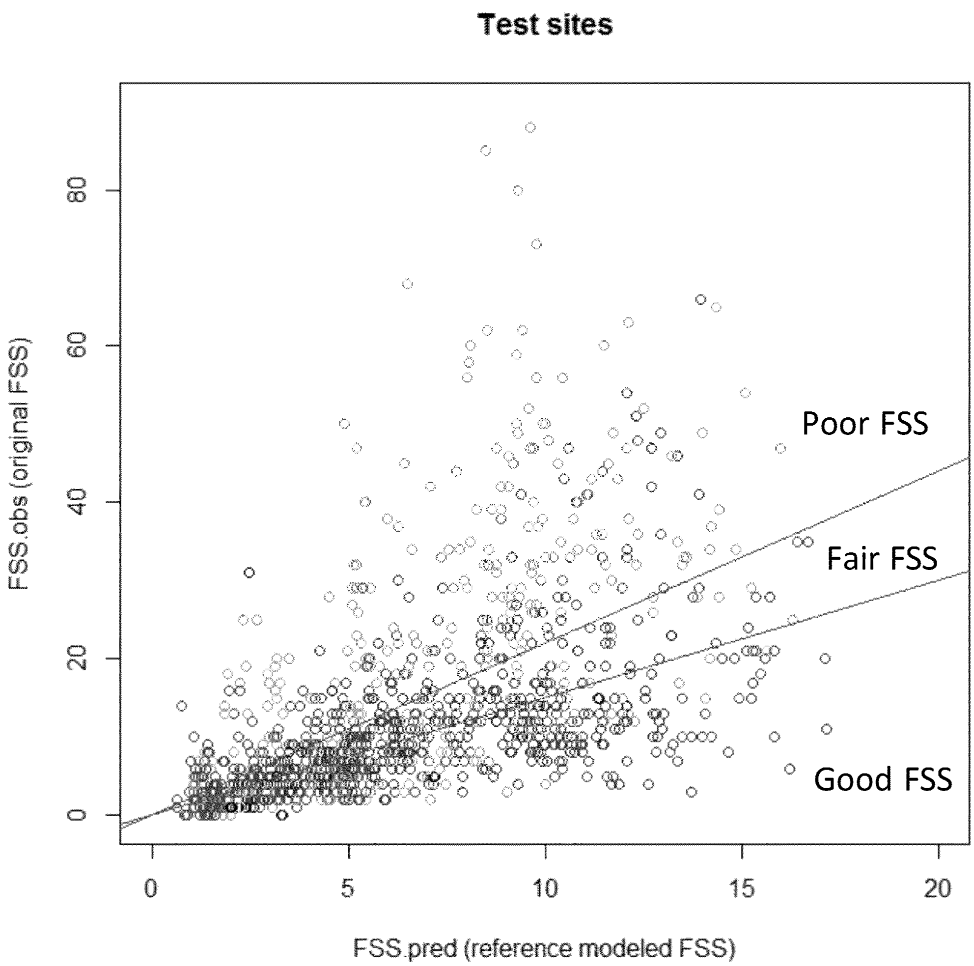
Modeling Results: key components

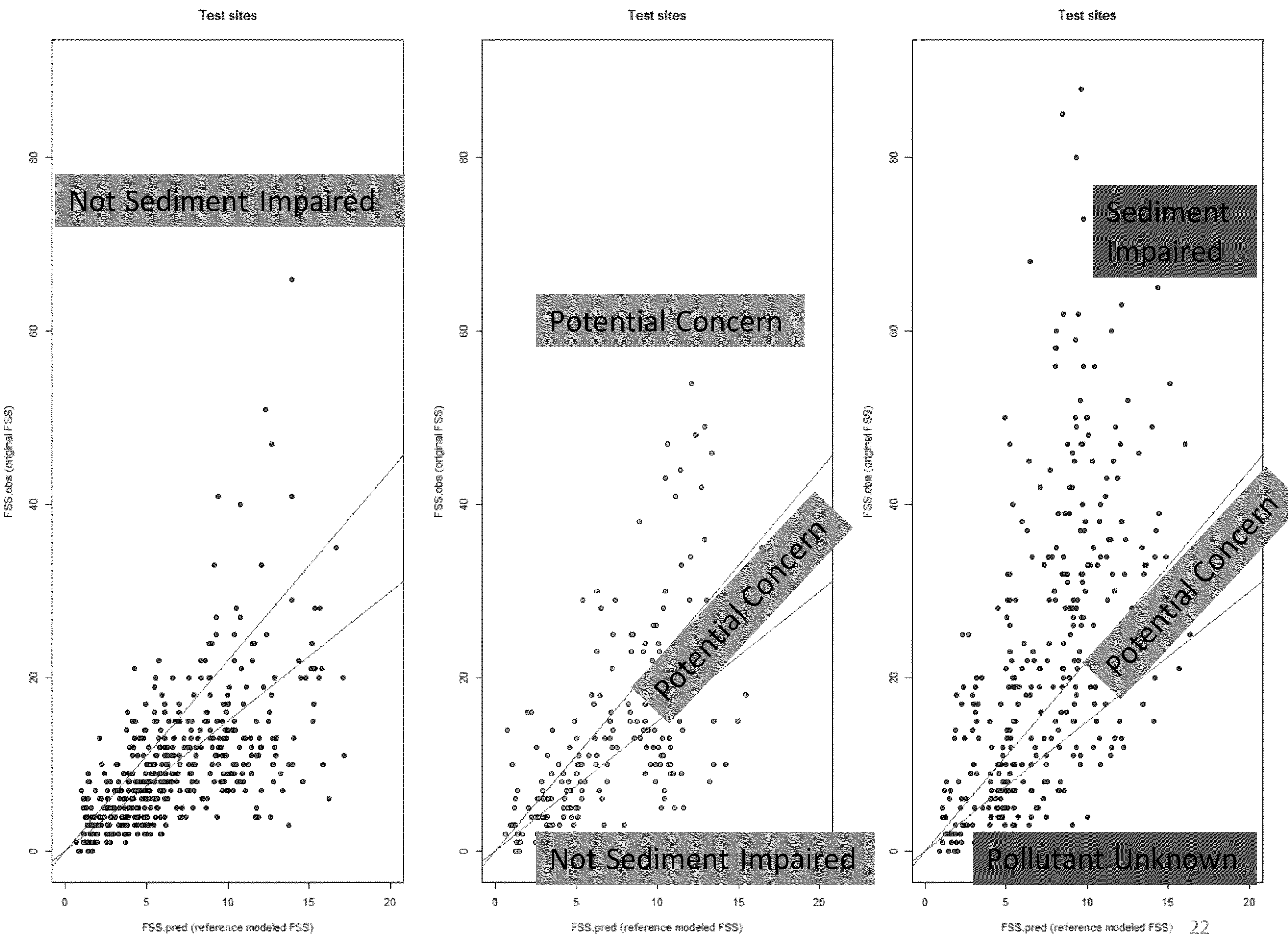
- FSS_{obs} = Observed
  - original FSS, based on bugs and abundances
- FSS_{exp} = Expected
  - modeled FSS
  - What we would expect FSS to be if a test site was in reference condition
- FSS_{resid} = How different is a test site from reference expectations?

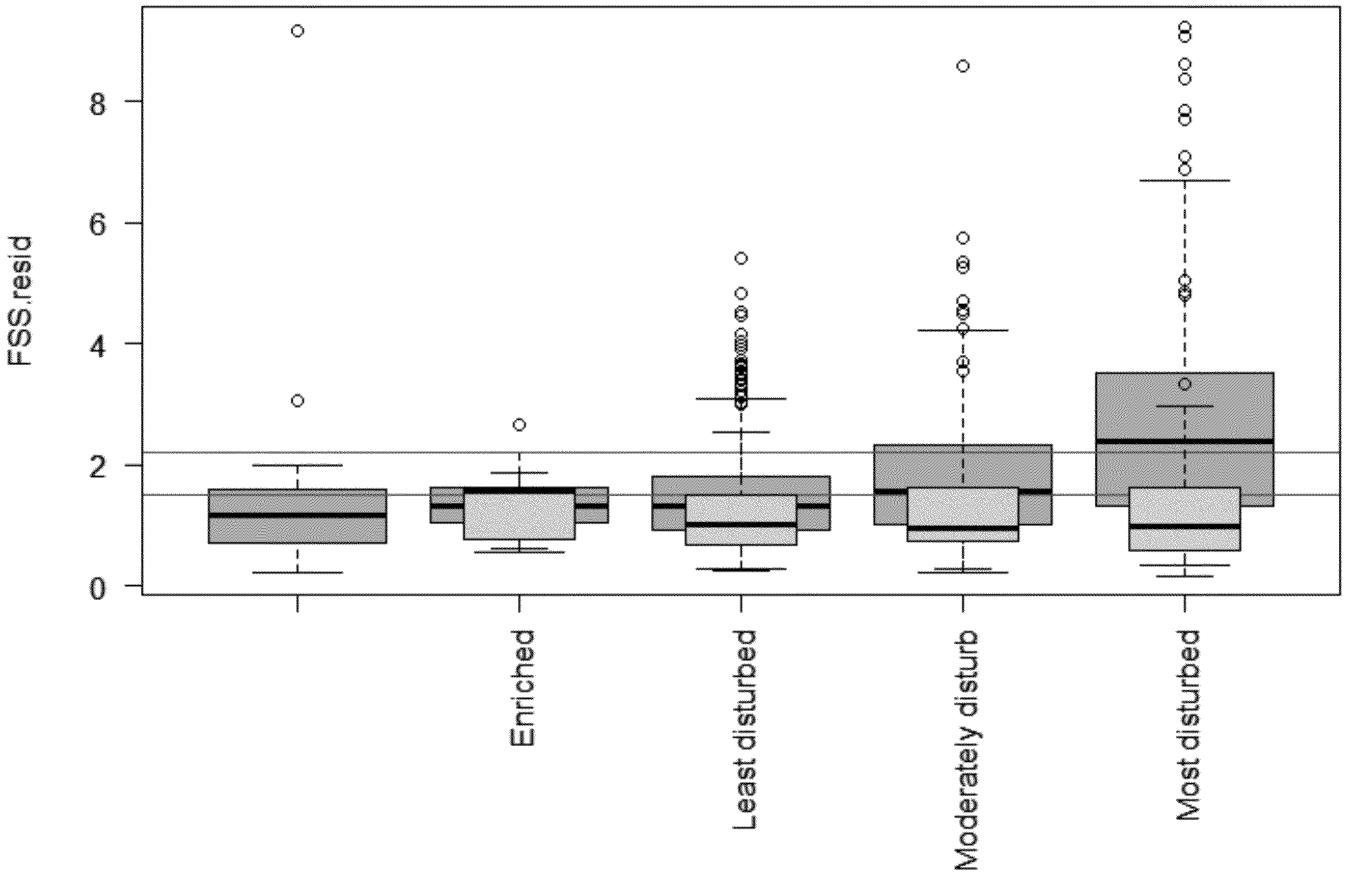

Histograms of residuals for reference (blue) and test (yellow) populations.
Vertical lines indicate good (left of green) and poor (right of red) conditions.
→ 10% of reference sites, 29% of test sites
Frequency
0
100
200
300
400
0
2
4
6
8
10
FSS(resid)

Summary

- We developed site specific expectations for the biological sediment index (FSS), assuming sites are in reference condition
- O/E approach
  - Is the observed >> expected?
- Sediment Impairments require a double whammy
  - Biocriteria (PREDATOR)
    - ≥ 15% taxa loss
  - Biological sediment index (FSS)
    - Observed ≥ 2.2*Expected
- 18% of test sites = Sediment Impaired (n = 193)


Test sites
FSS.obs (original FSS)
FSS.pred (reference modeled FSS)
Poor FSS
Fair FSS
Good FSS
0
20
40
60
80
0
5
10
15
20


Test sites
Not Sediment Impaired
FSS.obs (original FSS)
FSS.pred (reference modeled FSS)
Test sites
Potential Concern
Potential Concern
Not Sediment Impaired
FSS.obs (original FSS)
FSS.pred (reference modeled FSS)
Test sites
Sediment Impaired
Potential Concern
Pollutant Unknown
FSS.obs (original FSS)
FSS.pred (reference modeled FSS)


FSS.resid
0
2
4
6
8
Enriched
Least disturbed
Moderately disturb
Most disturbed

Advantages of the RF Residuals Approach

- Allows for site specific criteria
  - Each site has unique expectations, based on natural predictors that influence sediments
  - High FSS can be natural (within reference expectations)

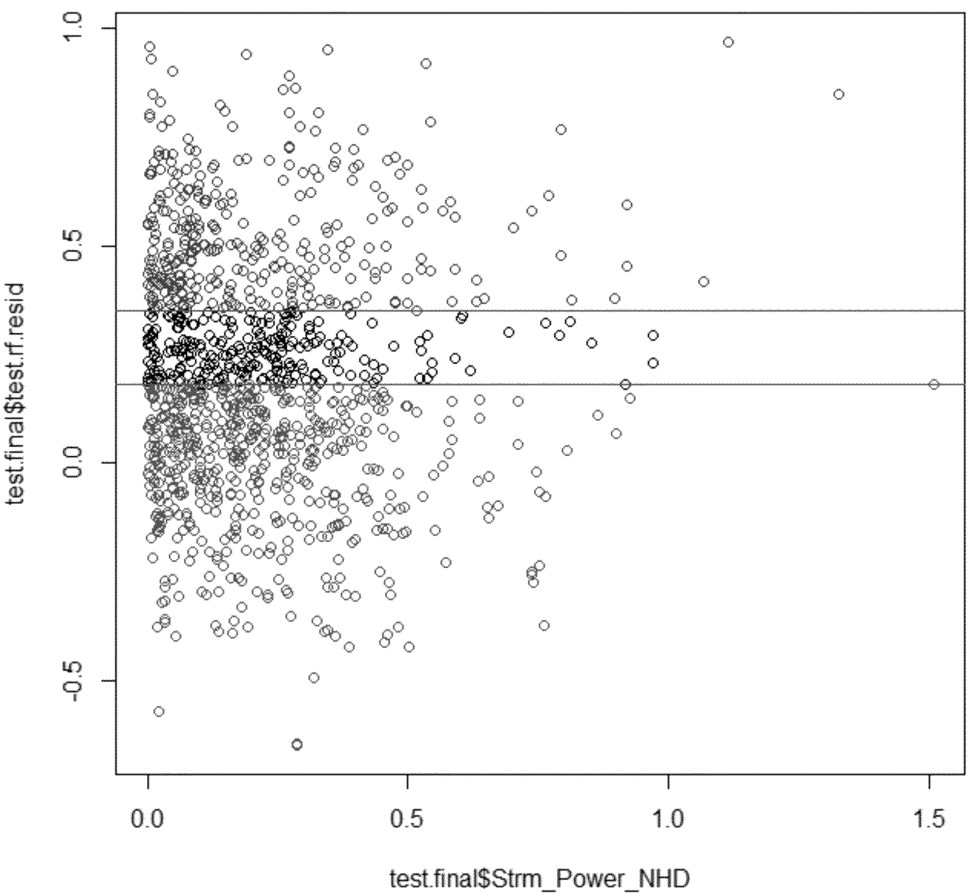
- Maximizes reference sample sizes

- Output is logical and easy to interpret
  - By how much does the observed FSS exceed reference expectations?

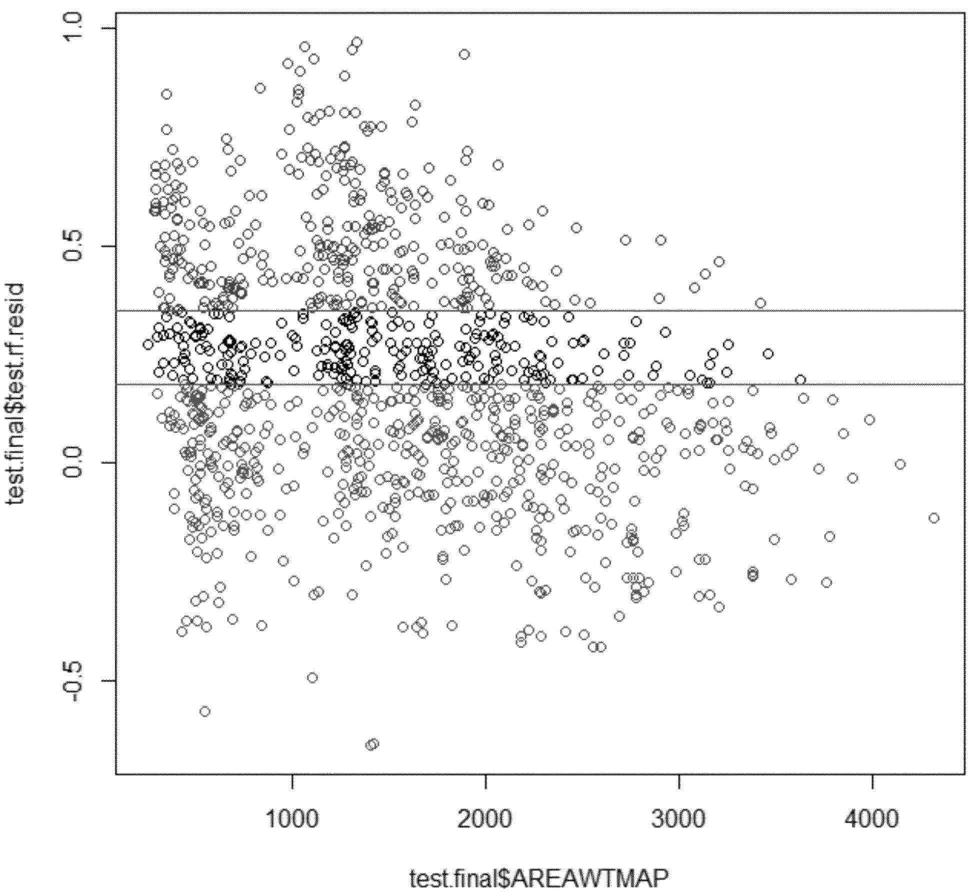
Lingering questions

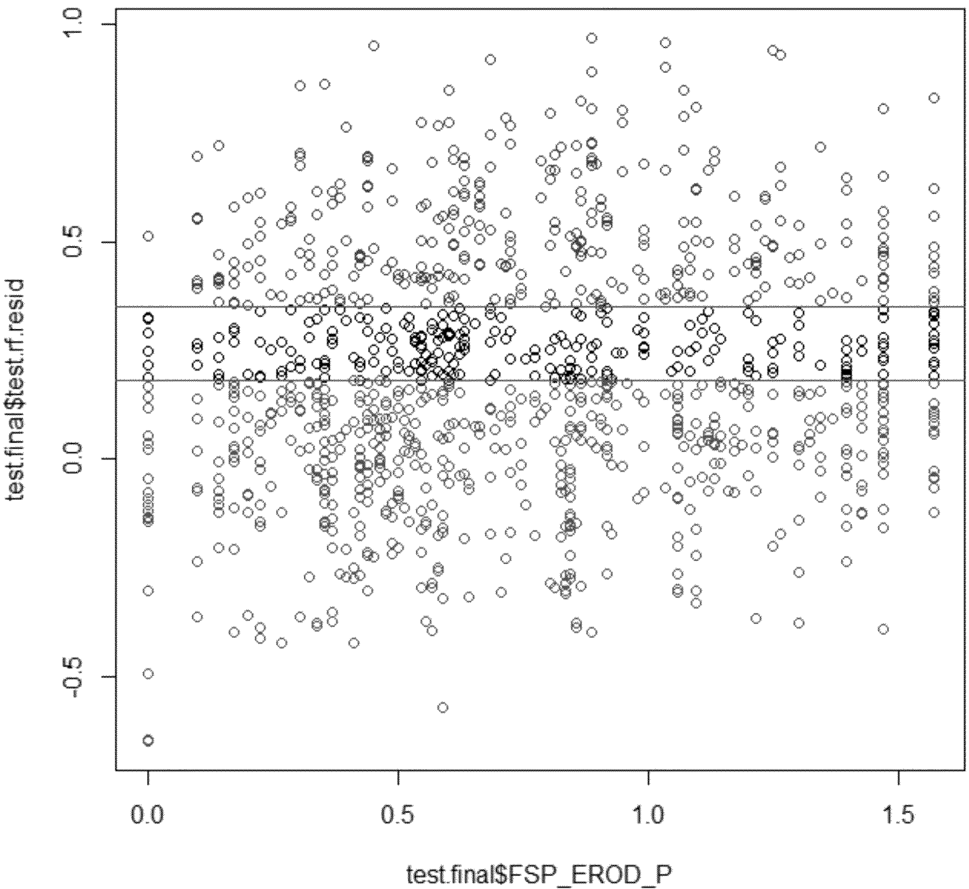
- Are there biases in predictive model for FSS?
  - FSS condition across natural gradients appears to be relatively unbiased
  - Possible biases
    - Higher precip = better FSS condition?
    - Lower slopes = worse FSS condition?
      - may be hard to tease out from human disturbances
- How well do reference sites characterize natural gradients across the landscape?
  - e.g., Are we biasing our predictions toward higher elevation, higher gradients, more resistant lithologies?

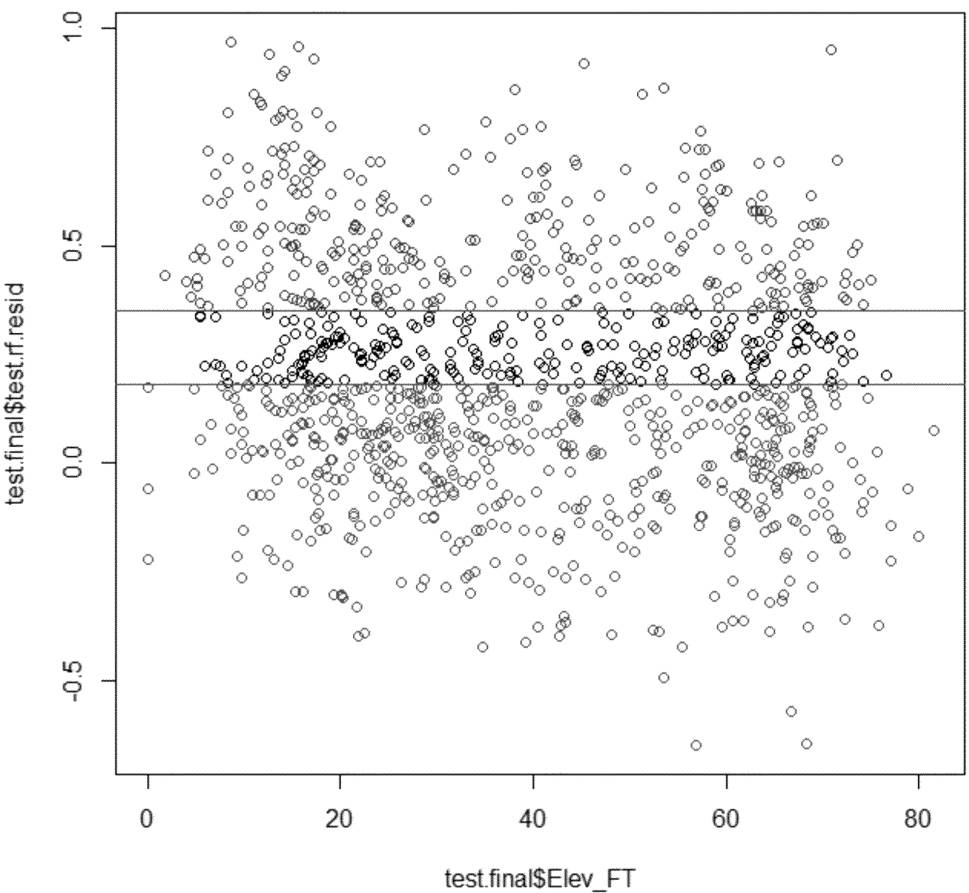
How does FSS.resid look across natural gradients?



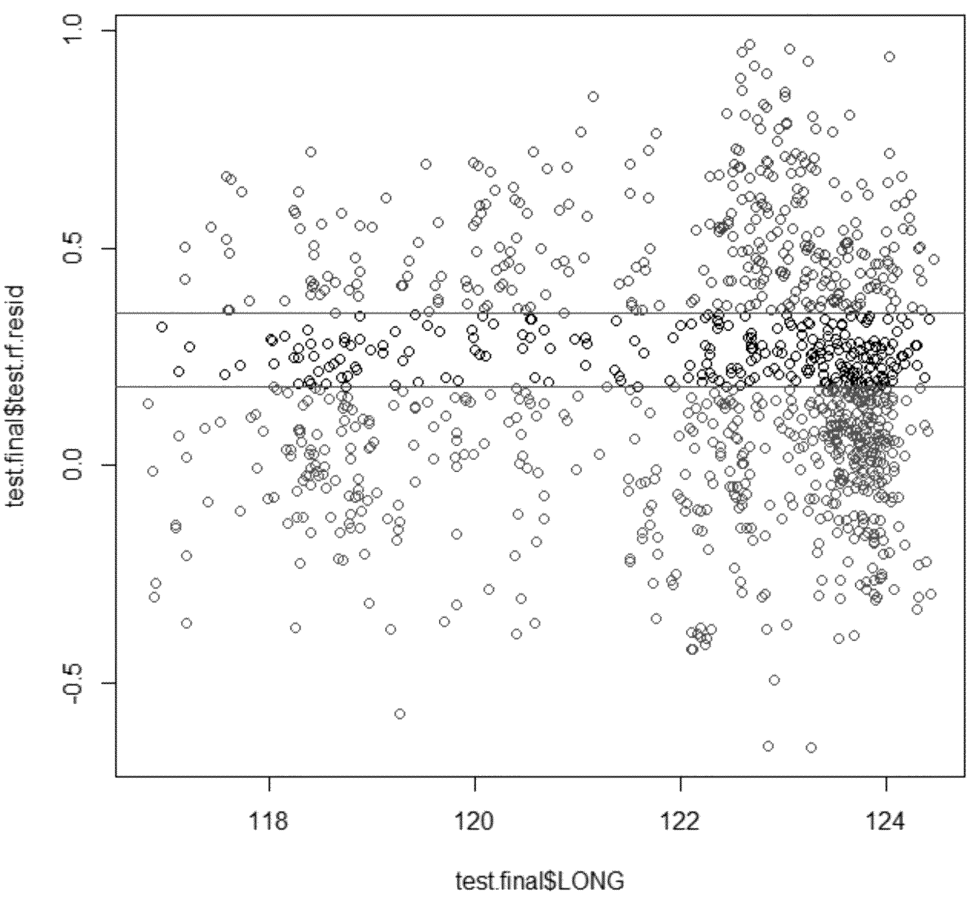
1.0
0.5
0.0
-0.5
test.final$test.rf.resid
0.0
0.5
1.0
1.5
test.final$Strm_Power_NHD

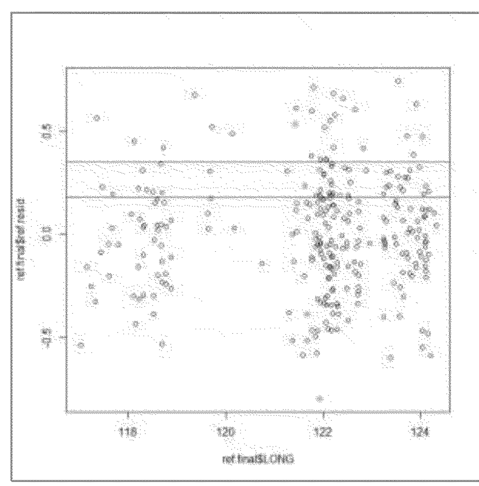

1.0
0.5
0.0
-0.5
test.final$test.rf.resid
1000
2000
3000
4000
test.final$AREAWTMAP

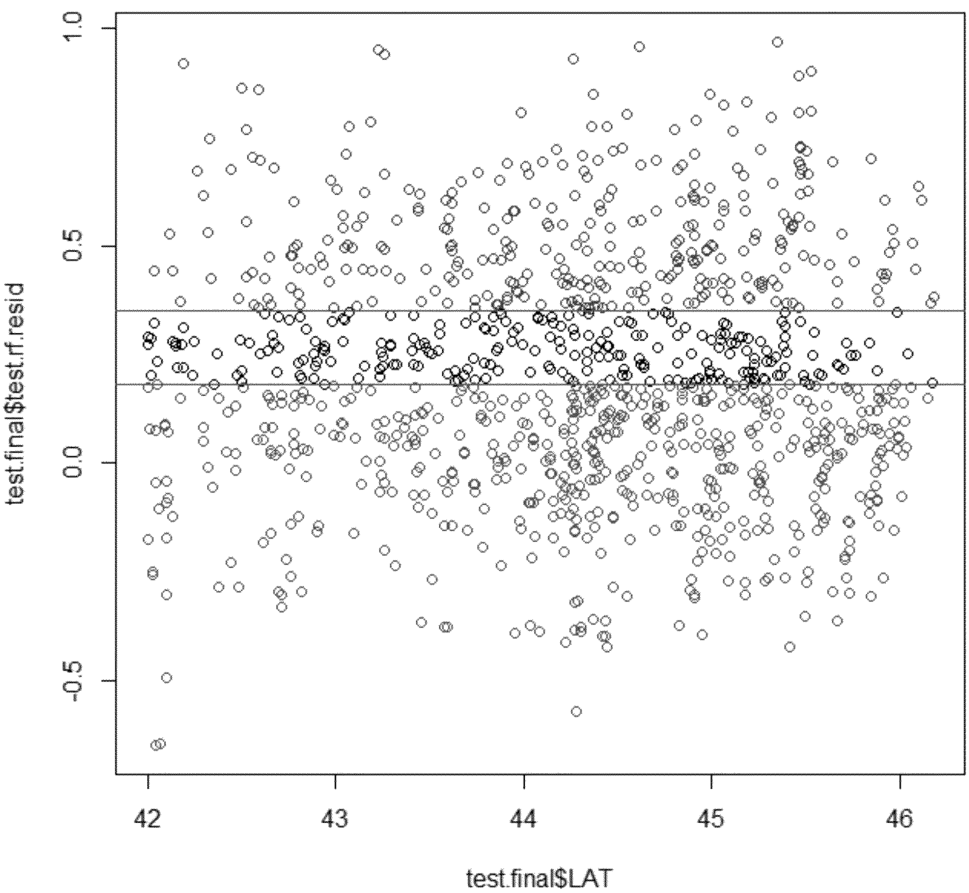

1.0
0.5
0.0
-0.5
test.final$test.rf.resid
0.0
0.5
1.0
1.5
test.final$FSP_EROD_P



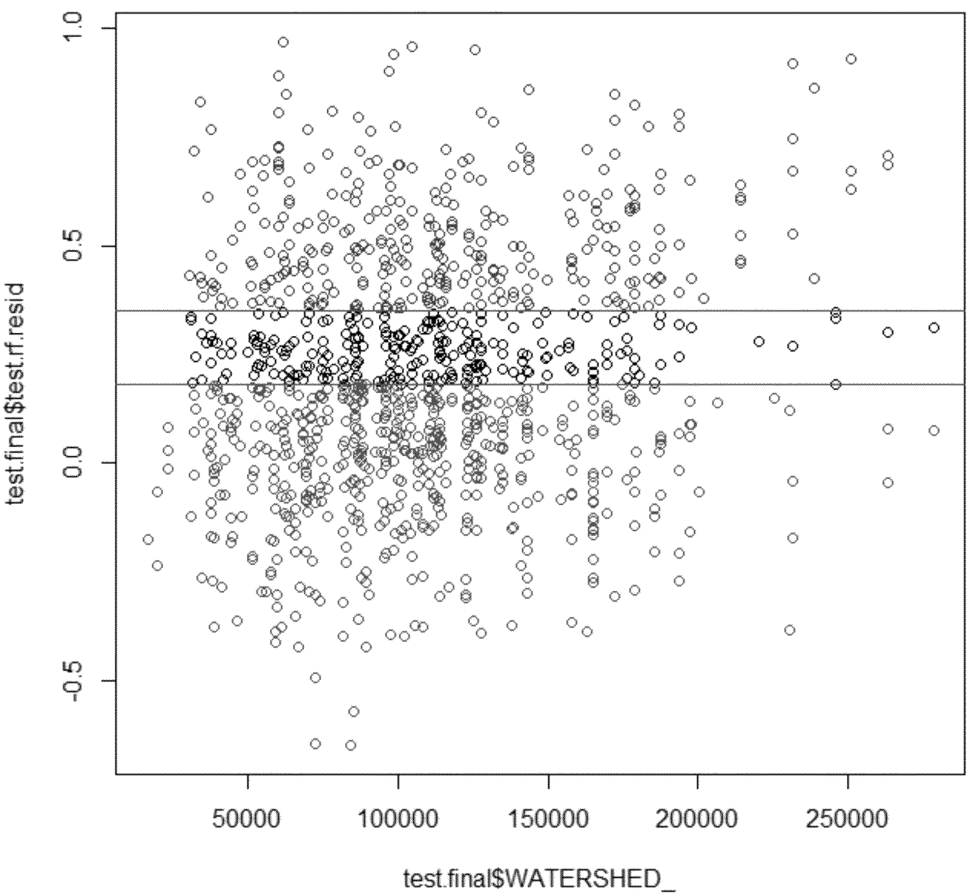
1.0
0.5
0.0
-0.5
test.final$test.rf.resid
0
20
40
60
80
test.final$Elev_FT


test.final$test.rf.resid
1.0
0.5
0.0
-0.5
118
120
122
124
test.final$LONG

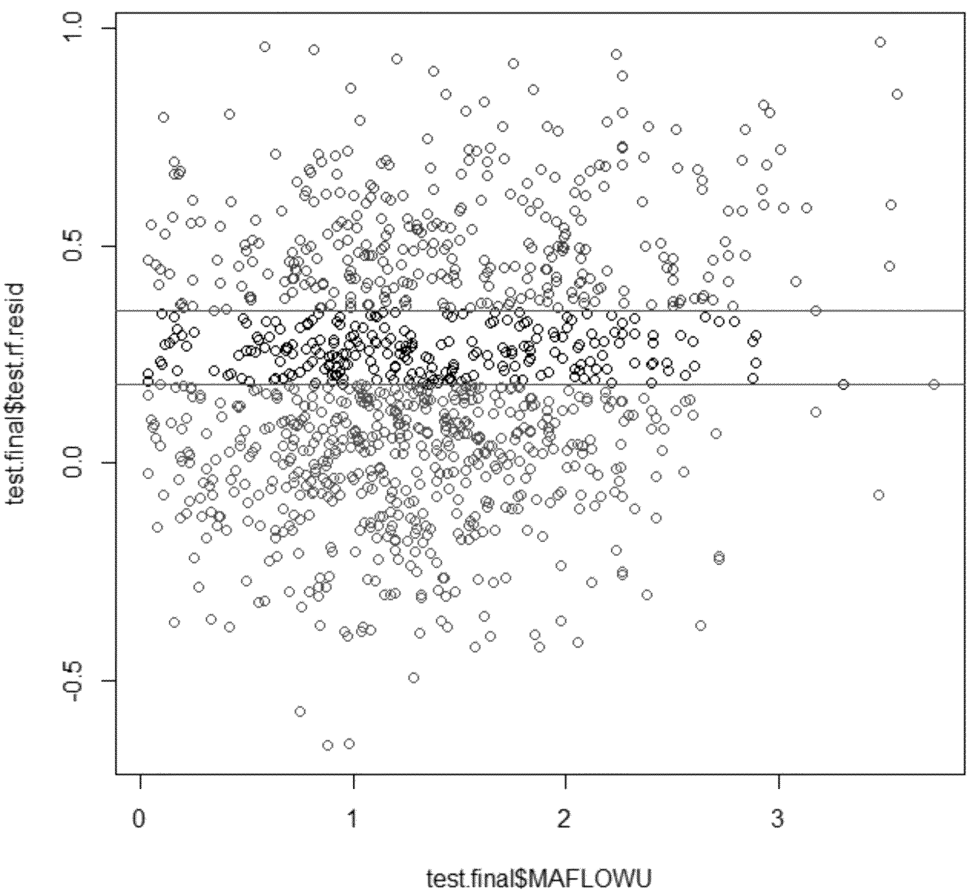

118
120
122
124



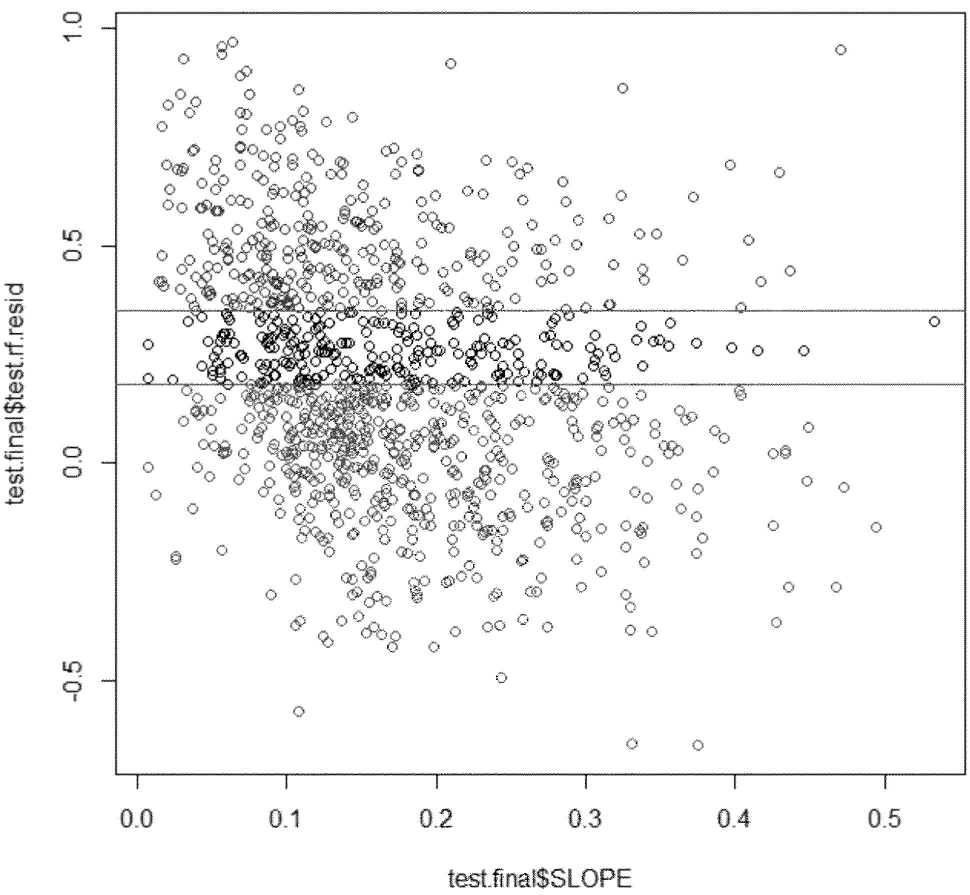
1.0
0.5
0.0
-0.5
test.final$test.rf.resid
42
43
44
45
46
test.final$LAT



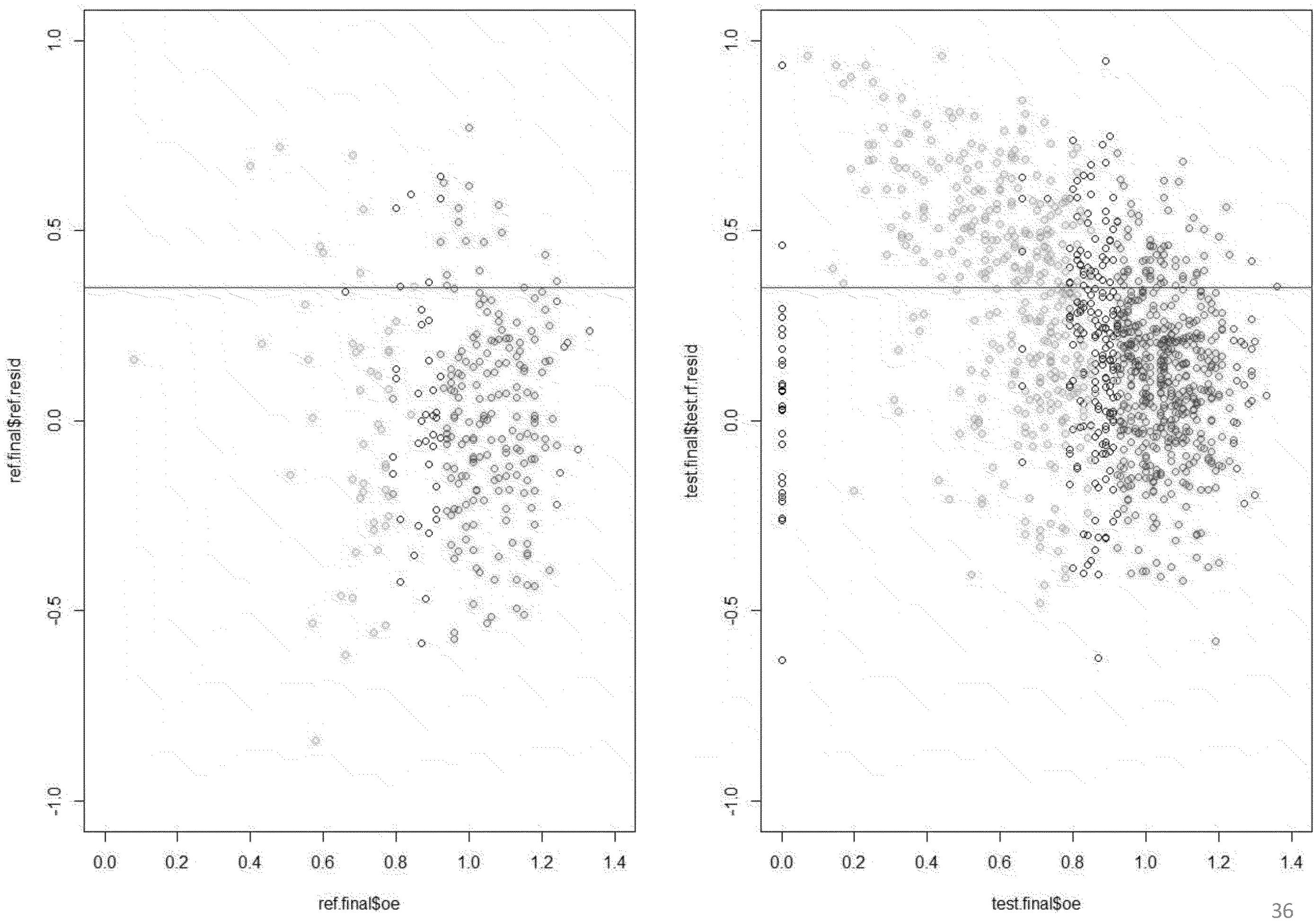
1.0
0.5
0.0
-0.5
test.final$test.rf.resid
50000
100000
150000
200000
250000
test.final$WATERSHED_



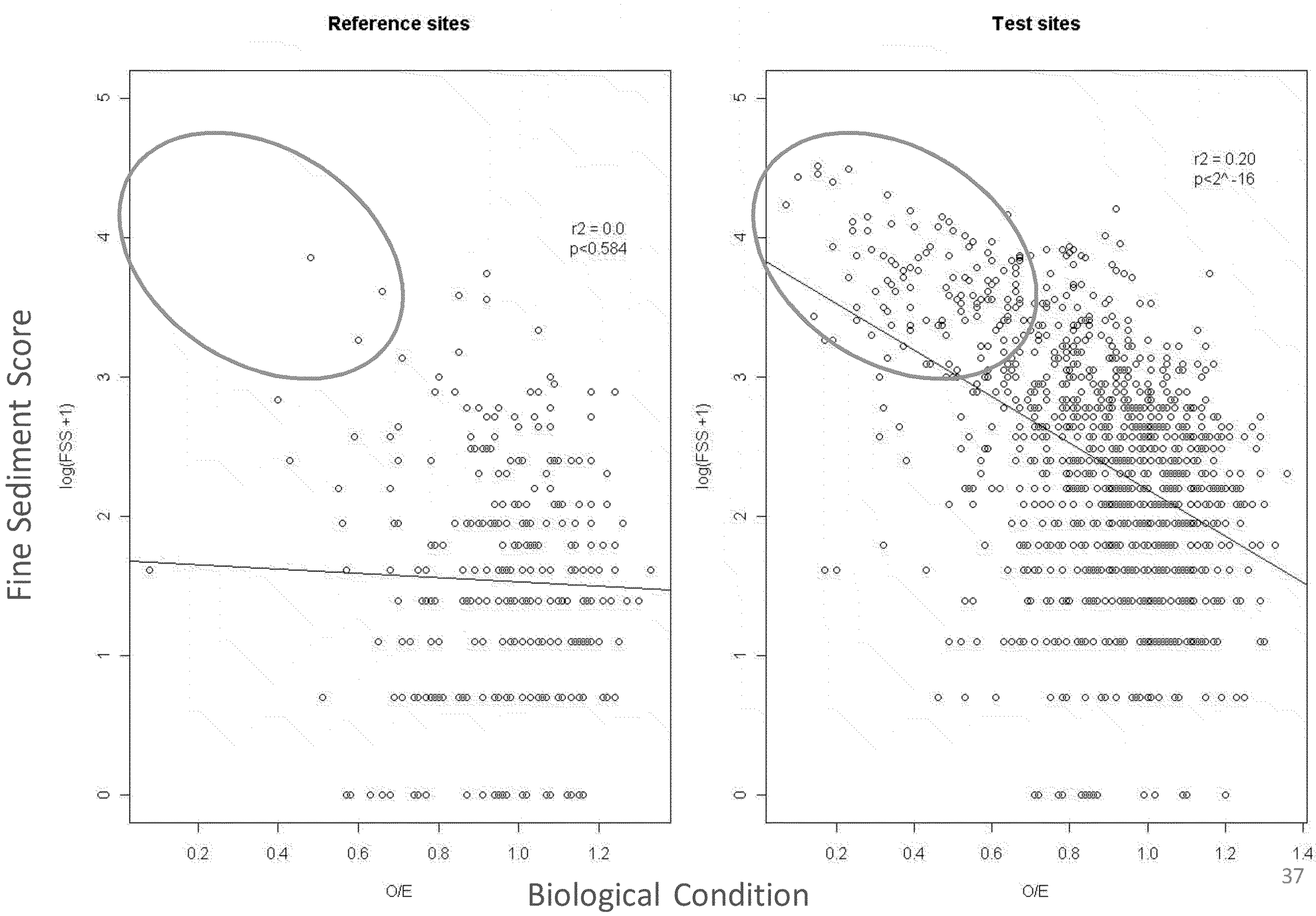
1.0
0.5
0.0
-0.5
test.final$test.rf.resid
0
1
2
3
test.final$MAFLOWU



1.0
0.5
0.0
-0.5
test.final$test.rf.resid
0.0
0.1
0.2
0.3
0.4
0.5
test.final$SLOPE


1.0
0.5
0.0
-0.5
-1.0
ref.final$ref.resid
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
ref.final$oe
test.final$test.rf.resid
test.final$oe

How does FSS relate to O/E?



Using residuals as reference benchmarks

- $FSS_{(resid)}$ = a multiplier effect
  - How many times greater is $FSS_{(obs)}$ than $FSS_{(pred)}$?

- RF model built on log10 transformed FSS
  - $\text{Log10}(FSS_{obs}) - \log10(FSS_{pred}) = FSS_{resid}$
  - $10\text{^}\,^{FSS.resid} * FSS_{pred} = FSS_{obs}$

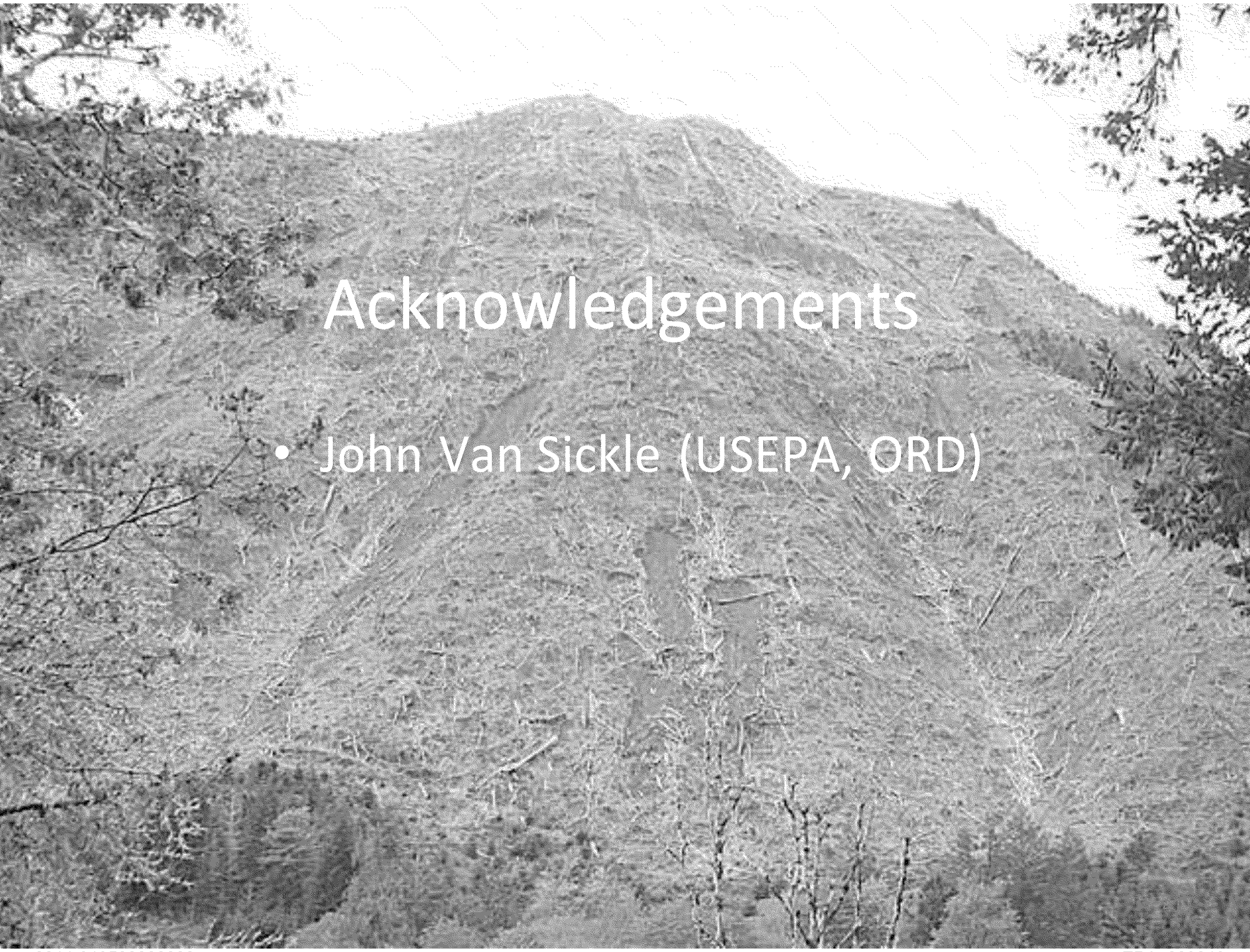
- 75th and 90th percentiles
  - Good: $FSS_{obs} < 1.5 * FSS_{pred}$
  - Poor: $FSS_{obs} > 2.2 * FSS_{pred}$

Applying this to non-reference sites

- Poor FSS
  - 29% of test sites
  - 319 test sites
    - 37 sites $FSS_{obs} < 10$
      - Mostly Cascades/E. Cascades/Klamath Mts.
        - » 1 Coast Range, 2 Willamette Valley, 2 Blue Mts.
      - Higher than average Precip, Stream Power, Slope,

Biocriteria Model: PREDATOR

- Predicts the bugs that should be found at a site, if the site were in reference conditions
- Observed/Expected
  - 7 bugs observed, 10 bug expected
  - O/E = 0.70
- Taxa Loss
  - 1 – O/E
  - 1 – 0.70 = 0.30 = 30% taxa loss
- Biocriteria violations
  - ≥ 15% taxa loss
    - Coast Range, Willamette Valley
  - ≥ 22% taxa loss
    - Cascades, Klamath Mts., E. Cascades, Blue Mts., Col. Plateau


Acknowledgements
• John Van Sickle (USEPA, ORD)